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Laser remote sensing for wind energy

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Laser remote sensing for wind energy

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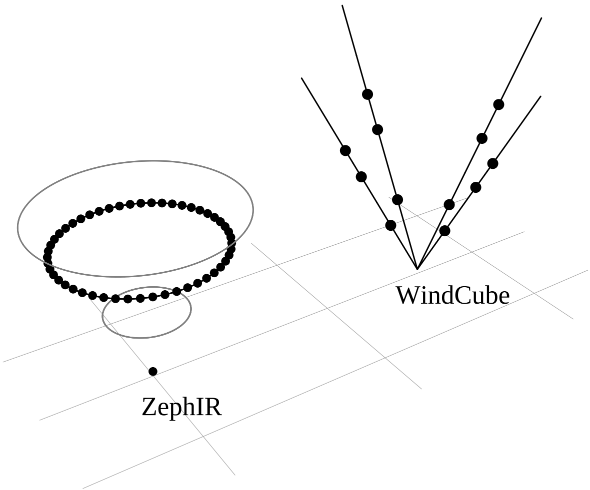
Doppler lidar instruments

continuous wave,pulsed



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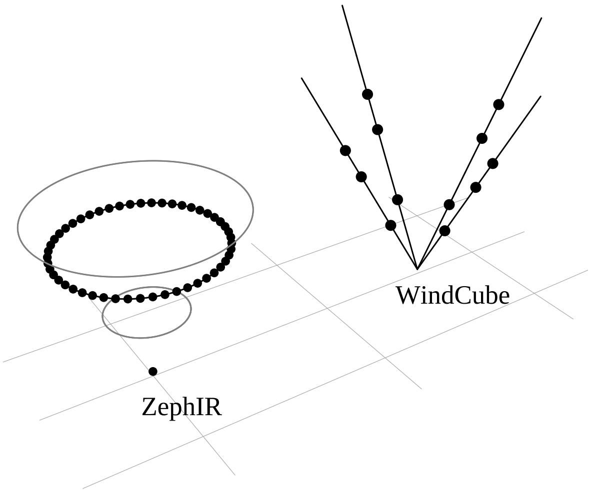

Some lidars for wind energy

Company	Instrument	properties and application
Natural Power	ZephIR300	RA, sea, control
Leosphere	WLS7, 70, 200	RA, meteorology, airports
Sgurr Energy	Galion	RA pulsed, flexible scan head
Catch the wind	Vindicator	yaw control, RA, 3 beam

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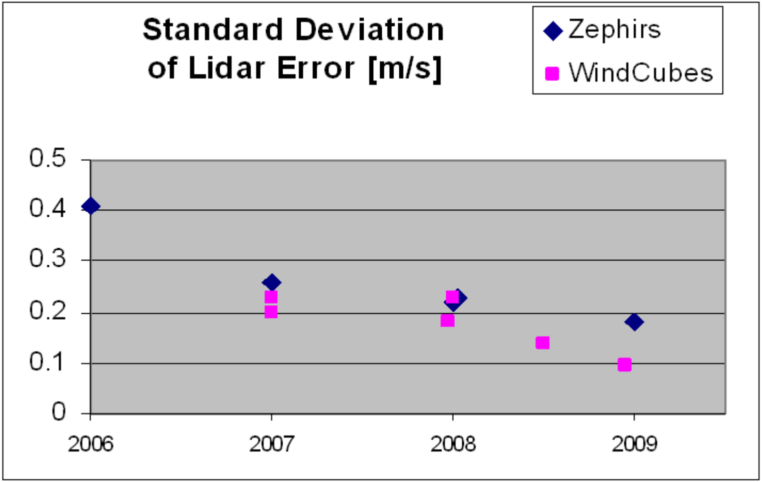
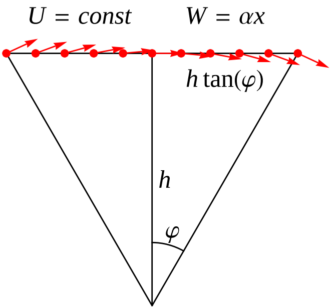
Mean wind speed measurements over flat terrain

ZephIR and WindCube

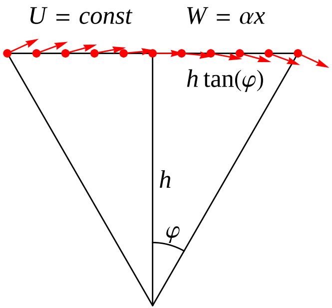


(Courtney *et al*, 2008 & 2011)

Conical scanning in non-homogeneous flow

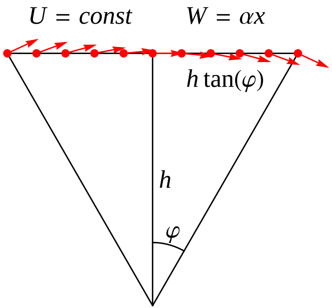


Conical scanning in non-homogeneous flow



$$\alpha = \frac{dW}{dx}$$

Conical scanning in non-homogeneous flow



$$\alpha = \frac{dW}{dx}$$

$$U_{lidar} = \frac{v_{down} - v_{up}}{2 \sin \varphi} = U + h\alpha$$

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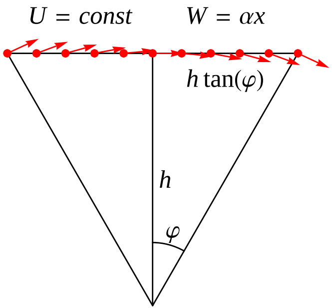

$$\alpha = \frac{dW}{dx}$$

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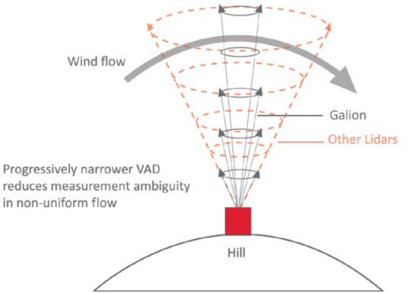
Does not depend on φ!

Smaller opening angle φ

A suggested solution

Ridge



Smaller opening angle φ

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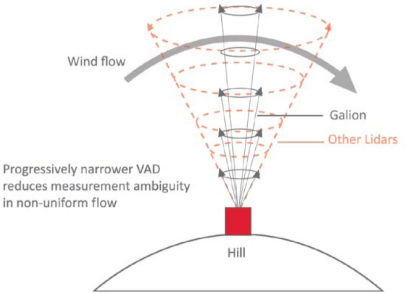

↯ Should not work in theory

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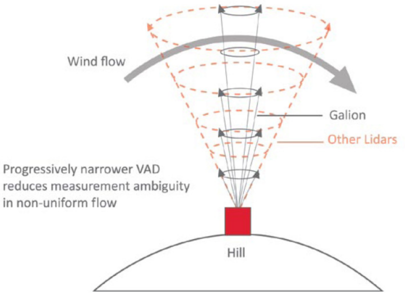
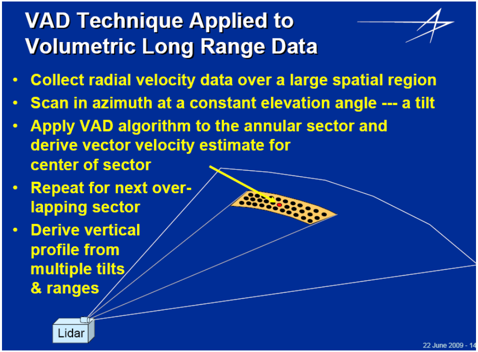


- ϟ Should not work in theory
- ϟ Has not been demonstrated in practice

Mapping wind speed over complex terrain

Lockheed Martin Coherent Technologies and RES



ϟStill systematic errors on wind components “perpendicular” to the beam

Other possible solutions

- Use flow models to calculate correction
  1. Bingöl et al 2009 *Met Zeit* (WAsP Engineering)
  2. Natural Power uses Ventos
  3. Leosphere uses Meteodyn

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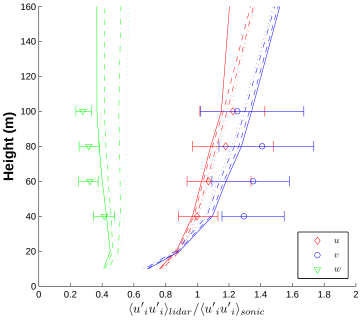
    2. Other wind resource estimation software
- *Use three lidars!*

Turbulence measurements over flat terrain works less well

Systematic error under different atmospheric stability conditions; WindCube: Unstable and stable



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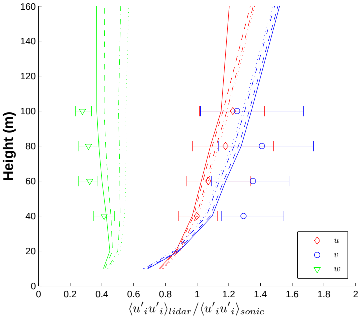
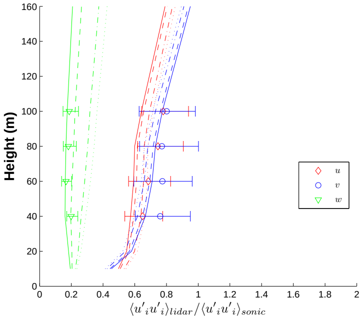
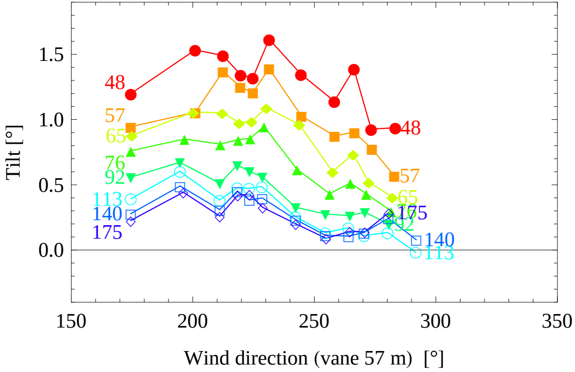




Measurement of flow angles over terrain

Small angles 400 m from a forest edge (Dellwik *et al Biogeosciences*, 2010)



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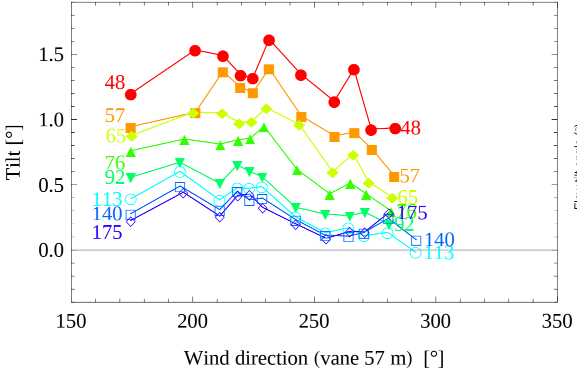
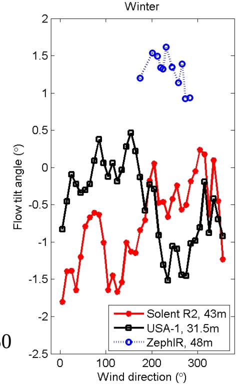




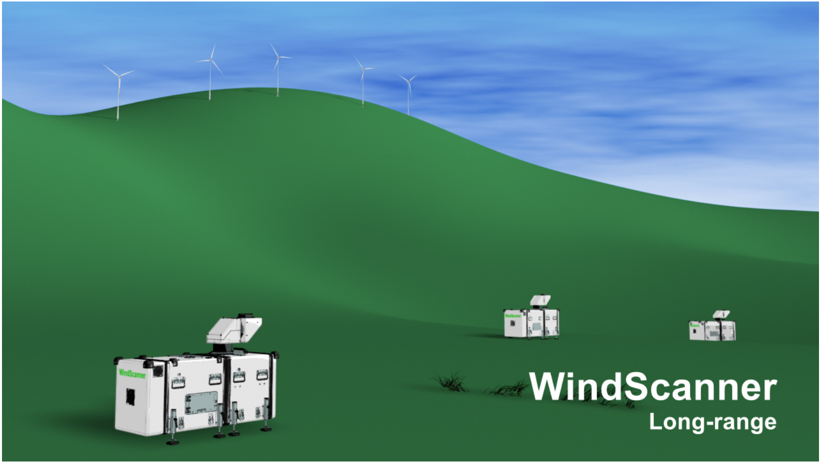
Short range wind scanner

Combine three ZephIRs and move the beams fast


WindScanner
Short-range WindScanner

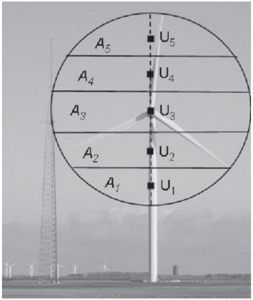
Long range wind scanner

Combine three WindCubes WLS200 and move the beams relatively slowly


WindScanner
Long-range

Power curves and control

- Power curves from profile measurements (IEC?)



Power curves and control

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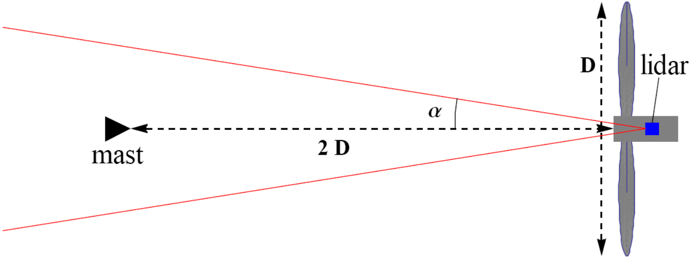
- Fast power curves from the nacelle



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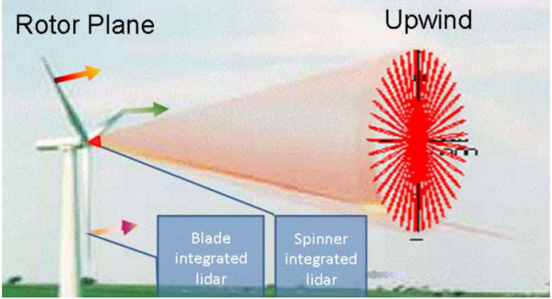
- Power curves from profile measurements (IEC?)
- Fast power curves from the nacelle
- Better yaw control
- Load reduction



Items to consider

- Wind lidars are very precise and suitable for resource estimation.
- Reliability is still an issue!
- There is a small bias on the wind speed measured by conically scanning lidars in complex terrain. Bias can be estimated.
- In contrast to mean wind speed, turbulence from lidars is biased even over flat terrain. We currently investigate ways to get more reliable turbulence estimates.
- Lidar technology opens new opportunities for wind turbine control, rapid power curve estimation, and research.

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